Selbyana 15(2): 14–17

A METHOD FOR ESTIMATING BARK SURFACE IN FOREST CANOPIES

CHRISTOPHER KERNAN[1]

The Department of Botany, The University of Texas at Austin, Austin, Texas 78713

ABSTRACT. A method to measure the amount of twig, branch, and trunk surface in forest canopies rapidly is described. The method uses variable-plot sampling with a forester's cruising prism to estimate the relative amount of surface at different canopy heights. These surface estimates can be subdivided into descriptive categories, allowing a quantitative description of surface distribution.

INTRODUCTION

Forest canopies harbor a tremendous variety and number of organisms. How these organisms are distributed in the canopy's light, moisture, and substrate environments reflects their adaptations to canopy habitats and their functioning within epiphytic communities. Measuring light and moisture gradients is relatively straightforward and has yielded useful insights (e.g., Pittendrigh 1948). In contrast, directly measuring twig, branch, and trunk surfaces dispersed in a forest volume is extremely difficult and tedious. Studies of the relationships between epiphytic organisms and their substrates have been hampered by lack of an efficient way to quantify canopy surface independently of the distributions and abundances of canopy organisms.

This paper describes a method to quantify bark surface in forest canopies and subdivide this surface into descriptive categories. Plots do not have to be laid out or measured individually. Instead, bark surface per unit of ground area is inferred from a sample of trunks and branches and certain geometric relationships as explained below. Choosing the sample is done with a cruising prism, which is fast and can be done without being close to each target branch or trunk. The method usually requires unambiguous, yes-or-no decisions making it inherently accurate.

The method is based on a modification of variable-plot sampling, a well-tested technique that has been used by foresters to estimate basal area and volume in timber cruising since it was invented by Walter Bitterlich in the late 1940's. Validation of the original method has been thoroughly documented in a large theoretical and empirical forestry literature (Bell & Dilworth 1989 and references within).

I have used the method successfully in studies of tropical epiphytic plant communities. It could be employed in other canopy studies that need a quantitative description of the relative area and characteristics of bark surfaces. Examples might include studies of bark-gleaning birds, arboreal territories of animals (e.g., ants, lizards), bark beetles, the distributions of other epiphytic plants, studies of forest structure and morphology, the vertical distribution of biomass, and certain studies of tree physiology and morphology. This paper briefly describes variable-plot sampling with a prism, presents a modification that allows prism sampling to be used for estimating surface rather than basal area, and discusses my experience using it in the field.

VARIABLE-PLOT PRISM SAMPLING

Describing a habitat quantitatively usually involves laying out plots of known area within which the presence of a habitat feature is measured. This measure of presence per unit area of plot is assumed to be a random variable with an expected value equal to the feature's presence in the habitat. A count within a unit area of plot is often a sufficient measure of presence if the feature is discrete and individual size is not important (e.g., simple occurrences of plant species, gopher mounds, animal tracks, etc.). Other habitat features, however, may need a measure of size instead of (or in addition to) counts (e.g., vegetation cover, diameter, basal area, etc.). Laying out a number of variously placed plots and then taking counts or counts plus a measure of size, is one way to quantify the presence and environmental distribution of a habitat feature.

In plotless sampling the distances of a sample of objects from a central point can be used to calculate an estimate of object frequency (Greig-Smith 1983). Variable-plot sampling is related to plotless sampling, but the objects included in the sample are determined by both their distances from a central sampling point and by object size. Plot area is adjusted to object size to give each counted object equal weight. A simple tally of such counted objects leads to an estimate of a habitat feature's presence per unit area that incorporates information about object size. Ob-

[1] Present address: Fairchild Tropical Garden Research Center, 11935 Old Cutler Rd., Miami, Florida 33156-4299.

ject tallies around points variously placed in the environment become a way to quantify spatial patterns of a habitat feature.

Choosing objects to include in a sample and then determining each object's proper plot size are critical steps. If the object has a diameter that does not vary with the side from which it is viewed, both steps can be accomplished rapidly and accurately using a forester's cruising prism. Cruising prisms are glass wedges ground to a slight angle, called the critical angle, that is typically less than 5 degrees. When looking through a prism, objects appear deflected to an extent that depends on the critical angle. Prism diopter is a measure of this optical deflection. When using a prism for variable-plot sampling, an object is tallied if the object's diameter is greater than the deflection caused by the prism. Taking a tree as an example of an object, this means that a tree is tallied if, when looking through a prism at the tree's trunk, the prism appears to shift a section of the trunk laterally less than the diameter of the trunk (FIGURE 1).

For a given prism diopter, the probability of tallying a tree depends on its diameter. Small-diameter trees must be close to the prism to be tallied; larger trees can be further away and their diameter will still exceed the prism deflection. The tally decision is usually unambiguous: the object's diameter either is, or is not, greater than the prism deflection. There are borderline cases, however, when the optical deflection exactly equals the diameter of the target object. At these borderline distances the tally is made, but given half weighting.

Small diopter prisms will tally more objects since their optical displacement will exceed object diameters at greater distances than prisms with large diopters. The choice of diopter, therefore, depends on the characteristics of the habitat. Small diopters are used in open habitats where objects are widely scattered. Large diopters are used in habitats with obscuring vegetation or where objects are common. In some circumstances, several prisms with different diopters can be used together to tally distinct classes of objects.

The plot area inferred for each tallied object is that of a circle with a radius equal to the borderline distance for the object's diameter. (The target object need not actually be at borderline distance.) The ratio between a tallied object's diameter and its borderline plot radius is the tangent of the prism's critical angle and is fixed by the choice of prism diopter. Any measure of the object that can be geometrically related to the object's diameter can be scaled to standard areal units using an appropriately derived multiplicative factor.

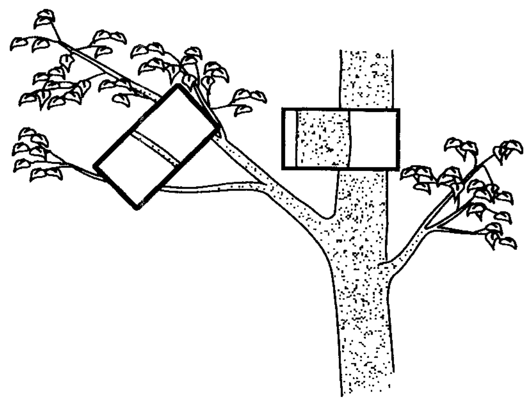
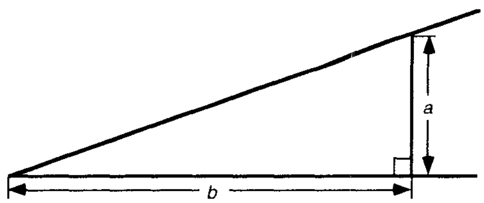


FIGURE 1. View through a prism at a target tree and branch. The trunk diameter exceeds the prism displacement and would be tallied. The branch would not be tallied.

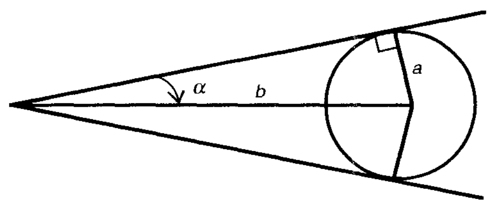
The diameter-related object measure that most commonly interests foresters is basal area. The ratio between a tallied tree's basal area and the area of its plot is fixed by prism diopter. A basal area factor (BAF) derived from this ratio scales the basal area of a single tallied tree to larger units of ground area. Because the ratio is constant, all tallied trees, regardless of their diameter, represent equal basal area when scaled to the same unit of ground area. The tally count accumulated in a sweep around a central point multiplied by BAF gives an estimate of basal area at a site. Foresters often use basal area directly as a relative indicator of timber volume, for example in monitoring stand growth from year to year, or in preliminary cruises to compare different timber stands. To estimate volume itself, foresters use empirical tables that relate basal area to volume given the tree's species and form class.

Circumference is another object measure related to diameter having a fixed geometric relationship with a plot of borderline radius. An estimate of bark surface can be based on the constant ratio between the circumference of a tallied branch or trunk and the circumference of this circular plot. As with basal area, tree and branch circumference can be scaled to standard units of ground area using an appropriately derived factor. In my studies of the tropical forest canopy, I used circumference as a relative indicator of bark surface area. This allowed comparisons of bark surface between different heights in the canopy and different forest habitats. I made no attempt to develop tables, analogous to foresters' volume-basal area tables, that would give true bark surface area, although this would be possible.

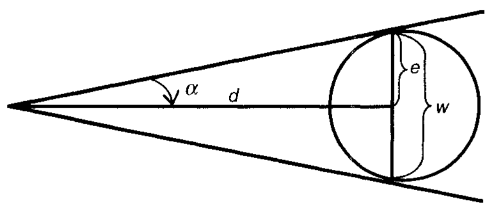
2



3



4



FIGURES 2–4. Reference diagrams for the derivation of circumference factor (CF). 2. Prism diopter = a/b when b = 100 units. 3. a = radius of target tree, b = radius of plot, α = one-half of critical angle. 4. w = visible diameter of the target tree in cm, e = one-half the visible diameter of the target tree, and d = the distance from the prism to the cord representing the visible diameter.

DERIVATION OF CIRCUMFERENCE FACTOR (CF)

What follows is a derivation of a factor that yields circumference per hectare (circumference factor, CF) given prism diopter. Prism diopter is the number of units of optical deflection per 100 units of distance between the prism and a target object. In FIGURE 2,

$$\text{prism diopter} = \frac{a}{b} \quad \text{when} \quad b = 100 \text{ units.}$$

In FIGURE 3,

$$\frac{\text{tree radius}}{\text{plot radius}} = \frac{a}{b} = \sin\alpha \quad \text{therefore,}$$

$$\frac{\text{tree circumference}}{\text{plot circumference}} = \frac{2\pi a}{2\pi b} = \sin\alpha.$$

This ratio is the same if projected to a per hectare basis:

$$\frac{\text{tree circumference}}{\text{plot circumference}} = \frac{\text{circumference per hectare}}{\text{circumference of 1 circular hectare}}$$

therefore,

$$\frac{\text{circumference per hectare}}{354.5 \text{ m}} = \sin\alpha.$$

Since

$$\sin\alpha = \frac{1}{\operatorname{cosec}\alpha},$$

$$\text{circumference per hectare} = \frac{354.5 \text{ m}}{\operatorname{cosec}\alpha}.$$

$\operatorname{cosec}\alpha = \sqrt{1 + \cot^2\alpha}$, therefore,

$$\text{circumference per hectare} = \left(\frac{354.5 \text{ m}}{\sqrt{1 + \cot^2\alpha}}\right).$$

In FIGURE 4, where w is the perceived diameter of the target tree,

$$\cot\alpha = \frac{d}{e} = \frac{d}{0.5w} = \frac{2d}{w}$$

and

$$\cot^2\alpha = 4\left(\frac{d}{w}\right)^2$$

therefore,

$$\text{circumference per hectare} = \left(\frac{354.5 \text{ m}}{\sqrt{1 + 4\left(\frac{d}{w}\right)^2}}\right),$$

or, since $\frac{d}{w}$ = the prism diopter,

$$\text{circumference per hectare} = \left(\frac{354.5 \text{ m}}{\sqrt{1 + 4(\text{diopter})^2}}\right),$$

and,

$$CF = \left(\frac{354.5 \text{ m}}{\sqrt{1 + 4(\text{diopter})^2}}\right).$$

DISCUSSION

I used variable-plot prism sampling and the formula for CF just derived in a study of a tropical epiphytic plant community in a lowland wet

forest canopy in Costa Rica. Variable-plot prism sampling allowed me to estimate both the total branch and trunk surface in the forest canopy and to subdivide that surface into categories reflecting spatial distribution and surface characteristics. I then used this distribution of bark area as an expected distribution of epiphytes and compared it to an observed distribution. This helped me develop hypotheses about the interactions between epiphyte species and the microsite characteristics available in the canopy habitat.

For my study, I made prism estimates at different levels of the lower canopy while ascending a rope. The visual tallying was particularly advantageous since it was not necessary to approach each tree to measure it, an impracticable task. Each tally was classified visually for categories of diameter, bark texture, species, epiphyte cover, etc., and the total surface estimate subdivided proportionately. Making a tally judgment was not difficult in most cases even if the target was partially obscured by vegetation. Only when the target was borderline was it necessary to make a careful sighting and hold the prism exactly over the center sampling point.

The method described here makes it possible to measure and plot branch and trunk surfaces in a forest canopy relatively easily. Canopy organisms live their lives mostly on the non-terrestrial surfaces of a forest; they grow, perch, forage, defend territories, reproduce, and die on such surfaces. A simple field method that allows this surface to be described and measured accurately is useful in studies of many canopy organisms other than epiphytic plants.

Acknowledgments

This work was funded in part by a Sigma Xi grant and fellowships from The University of Texas at Austin. I thank the Costa Rican Park Service and the administrators of Corcovado National Park, particularly Miguel Madrigal, Orlando Montero, and Eliezer Arce. L. E. Gilbert, Director of The Brackenridge Field Laboratory of The University of Texas at Austin generously provided office space. I thank B. B. Simpson, L. E. Gilbert, N. L. Fowler, P. Phillips, D. Cornejo, and M. Bonness for their support and constructive criticism.

Literature Cited

Bell J. F. and J. R. Dilworth Jr. 1989. Variable plot sampling: variable plot and three-p. O.S.U. Bookstores, Corvallis.

Greig-Smith P. 1983. Quantitative plant ecology. U. of California Press, Berkeley, Los Angeles.

Pittendrigh C. S. 1948. The bromeliad-Anopheles-malaria complex in Trinidad. I The bromeliad flora. Evolution 2: 58–89.